

Print this pdf file on 2-sides of A3
paper (flip on the short side).

Then cut all pages in half horizontally,
arrange in order, fold, staple, and you
will have a book.

Did you believe everything you read in this book? ... I hope not.
If you were thinking like a scientist, you should have been questioning what you read!

For example, how do we know where crops like cabbage and cauliflower came from?

This question is currently being investigated by scientists. Scientists do not find cabbage and cauliflower growing in the wild. But they do find various types of wild mustard plants. This is in line with the possibility that cabbage and cauliflower were produced by artificial selection, not natural selection.

You can find evidence that various plants in the mustard family are related by comparing the forms of their flowers, leaves, roots, and other parts. You can also compare their taste to other vegetables. Scientists have found substances called glucosinolates in plants in the mustard family, which give them a characteristic taste.

By determining the DNA sequences of the wild and cultivated varieties, scientists find that they are related. DNA sequences also give evidence about how different the plants are and how long ago they diverged, forming new populations with different characteristics.

Scientists have looked for historical, archaeological, and geologic evidence to find out when and where crops like cabbage first appeared. For example, more than 2000 years ago the ancient Greeks wrote about growing cabbage. People have found seeds in the ruins of ancient cities, and have determined the ages of the seeds. Although traces of some wild mustards have been found in very ancient fossils, no traces of cabbage, cauliflower, or mooli have been found which are so ancient.

Recent evidence of the above types suggests that people may have first produced populations of cabbage from populations of wild mustard, then people produced populations of cauliflower from populations of cabbage, both through the process of artificial selection.

Why is this research important? Will it help us understand mustard and evaluate methods of selection, so that we can continue to produce new kinds of crops?



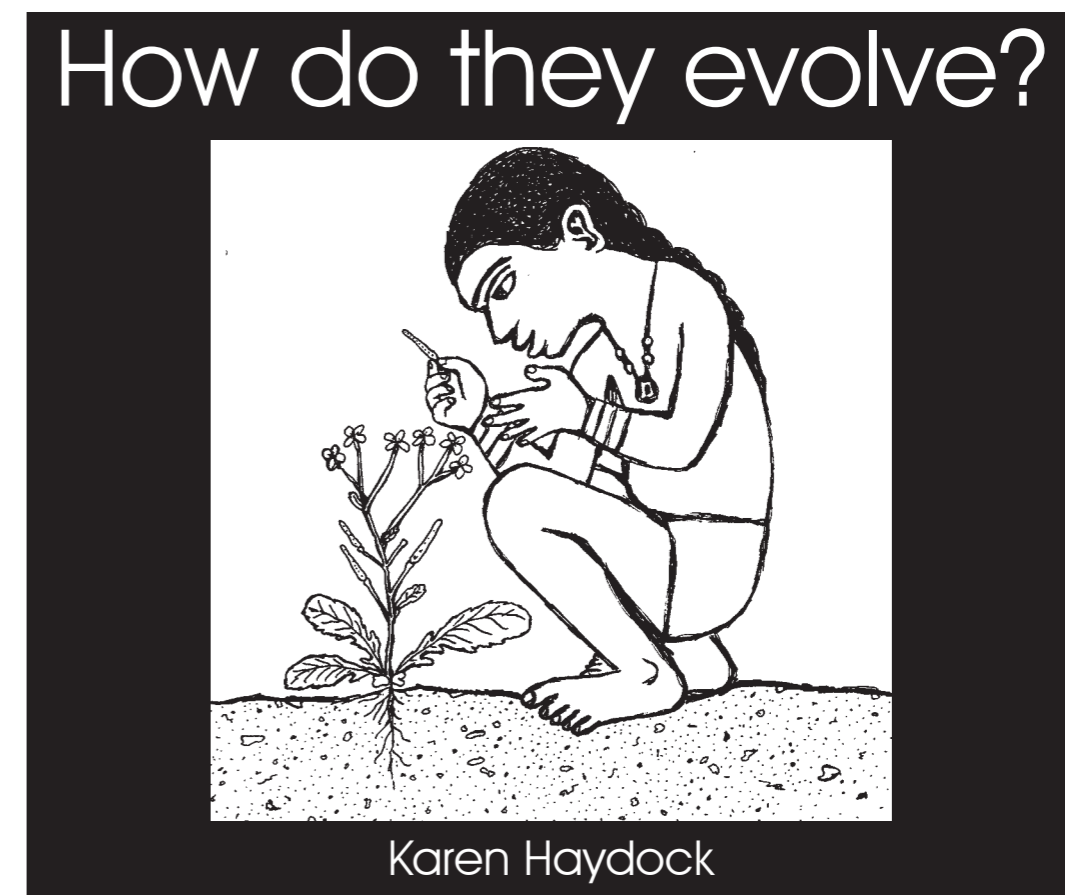
And how can we possibly know whether mustard with long roots was produced by natural selection due to floods?

Actually, that was just a hypothesis. We need to collect more evidence to know how good a hypothesis it is.

...And did those beetles really write that plan?

This book is written just to give you a few ideas.

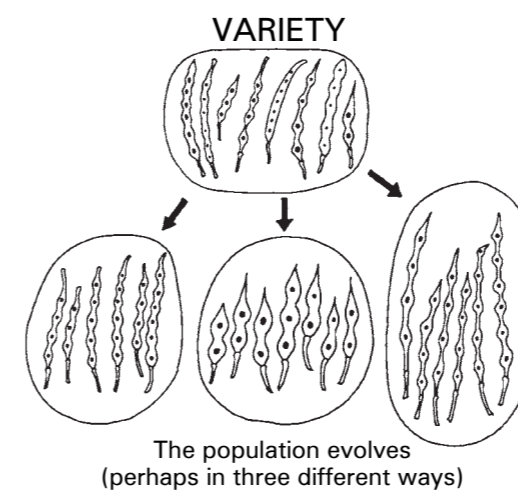
Now it is up to you to ask questions, investigate further and find out more...



Many many years ago,
before your parents were born,
and before your parents' parents were born,
and before their parents', parents', parents were born, there
were different food plants than there are now.



Before this, there was even a
time when there were no fields
of crops grown by farmers - in
fact, there were no farmers!
People gathered food that was
growing wild instead of growing
it in fields.



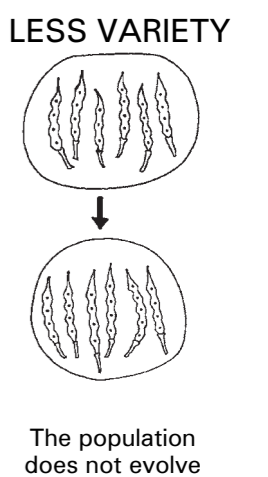
Loss of variety is a serious problem

Nowadays seed companies try to get all
farmers to buy a particular kind of seed they
have developed. As a result, the number of
varieties of many crops are decreasing.

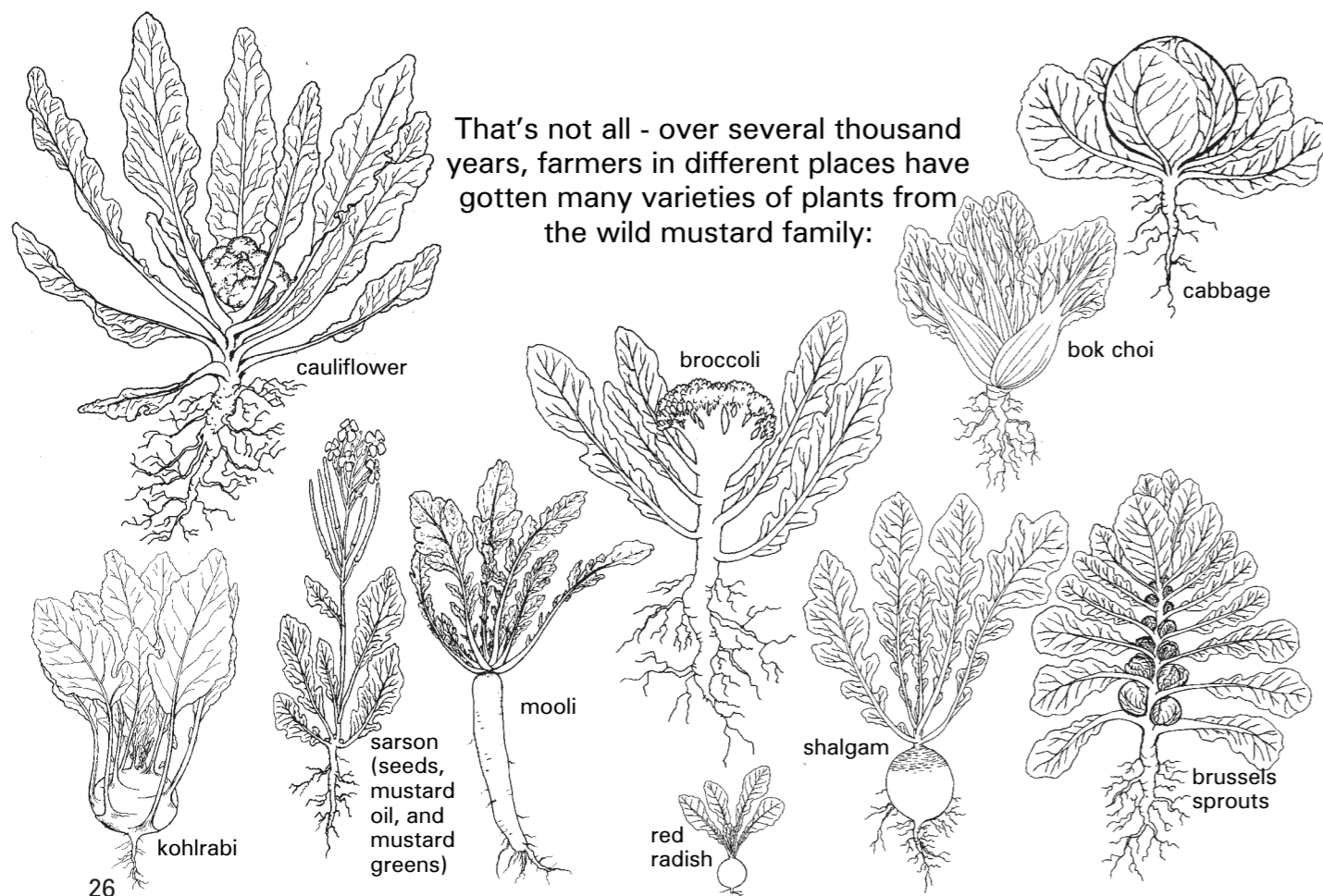
For example, people in the same village, or in
different villages, used to grow many different
varieties of rice. Now just a few different
kinds are grown.

But everything is interconnected and
everything keeps changing. So a variety that
was good a few years ago may not be so good
now - it may have become less resistant to
some new fungus or beetle. We may need to
develop new varieties of rice. But how can we
do this if we do not have a variety of plants to
choose from?

Therefore it is important to encourage a
diversity of varieties, and to prevent the
extinction of varieties which may one day be
useful.



Evolution depends on having populations
in which there are a variety of individuals.



That's not all - over several thousand years, farmers in different places have gotten many varieties of plants from the wild mustard family:

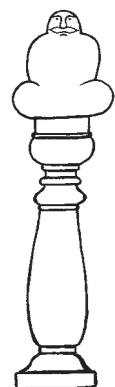
All of these were produced by people selecting the kinds of plants they wanted.

This is called **artificial selection**.

Here 'artificial' means 'produced by people'.

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Who decides?

No one decides what will happen in **natural selection**.

But in **artificial selection** who decides?

Did the people who planted the seeds decide which seeds to plant?

Or did someone else tell them which seeds to plant?

Did the zamindar decide? Did the king decide?

And is it different nowadays? Nowadays does the government decide? Do the seed companies decide? Do ordinary people decide?

How are the decisions made?

Is it based on which plants give the best taste?

The best colour? The largest size?

Or is it the ones that are easy to harvest?

Is it decided on the basis of profit and loss?

Is it decided on the basis of need or on the basis of desire?

Are the wrong decisions sometimes made?

Who should make decisions, and on what basis?



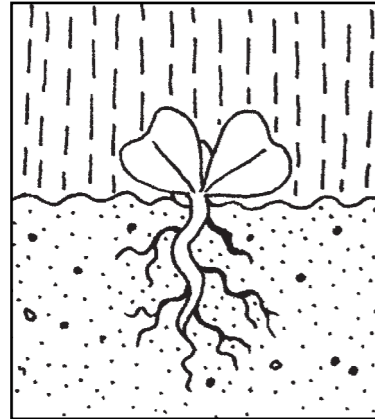
If the master decides, what seeds the slave will plant, will the master make the right decision? Some masters may be better than other masters. But there is no such thing as a good master.



In the days when farming was just beginning, there were some kinds of wild mustard plants.

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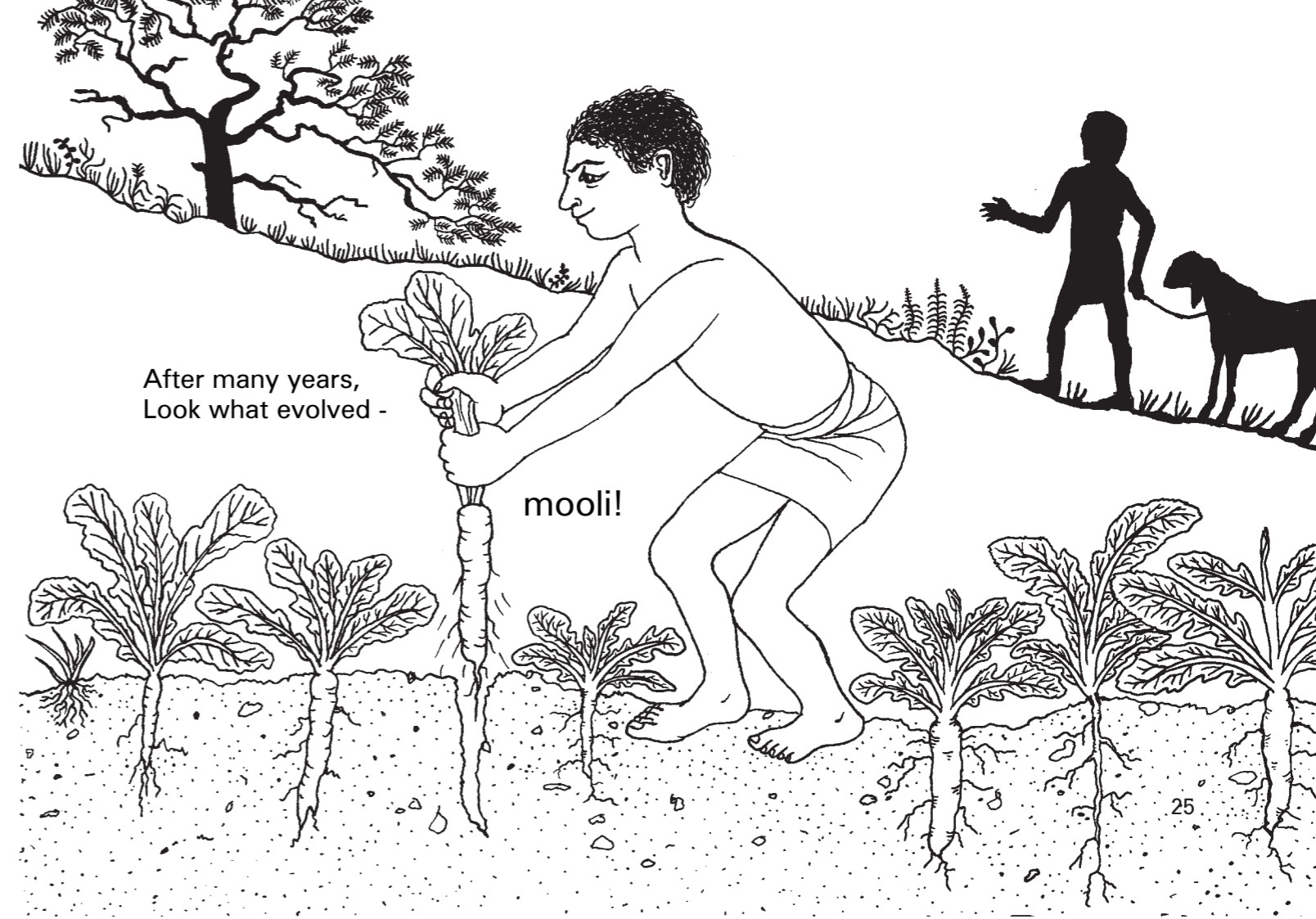


Sometimes people don't get what they want by artificial selection.

Sometimes a plant has larger roots just because the plant got more water.

Seeds from these plants may grow into plants with small roots the next year, if they do not get so much water.

The size of the roots is not determined just by the seeds.



Our ancestors took seeds from this wild mustard and planted them in fields.

Other methods people use to produce new kinds of plants

Hybrid plants

By pollinating one kind of plant with the pollen from another variety or related kind of plant, we can breed plants with new characteristics.

Scientists have produced many kinds of hybrid rice, hybrid wheat, and hybrid vegetables. Hybrids may have disadvantages as well as advantages. For example, the yield may be greater, but new seeds have to be purchased each year.

Genetic Modification (GM)

Using modern methods of genetic engineering and molecular biology, new types of plants can be produced.

Some questions arise concerning GM crops:

Will the new plants cause allergies or other diseases in people?

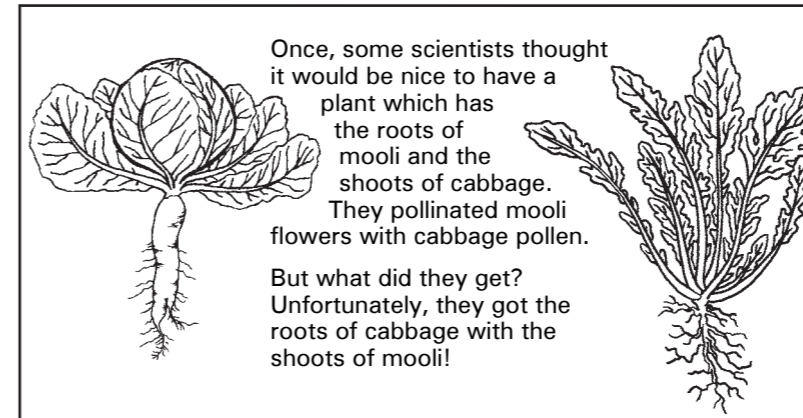
Will the new plant or its genes give rise to uncontrollable weeds?

Will the new plant adversely affect insects or other animals? How will it change its environment?

Will the new plant be more expensive for farmers to grow?

Maybe we could get mangomustard by GM...

but maybe the mangomustard would be poisonous!



So they planted the seeds from these plants. Each year farmers saved the seeds that gave plants with thick, tasty roots, and they used them to plant the next crop.

Sometimes seeds from plants with one desirable characteristic end up producing new plants with some unwanted characteristic.

For example, we may get a larger cabbage, but it may be bitter.

One characteristic may affect another characteristic.



What is evolution by natural selection?

(1) There is variation between the individual organisms that make up any population.

(2) This variation occurs partly because there are random mutations in the genome (differences in the DNA) of individual organisms. These mutations can be passed to offspring.

(3) Throughout the individuals' lives, their genomes interact with their environments to cause variations in traits. (The environment of a genome includes the molecular biology in the cell, other cells, other individuals, populations, species, as well as the abiotic environment.)

(4) Individuals with certain variants of the traits may survive and reproduce more than individuals with other variants.

(5) Therefore the population evolves.

How do we know that evolution by natural selection occurs?

(1) We do not find any population without variation.

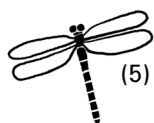
(2) We know that heritable mutations occur because we find them by DNA sequencing of individuals and their offspring.

(3) We find correlations between mutations and traits. We also observe that mutations cause changes in proteins. However, due to the complex interdependencies between the genome and its environment, we usually cannot say whether a particular mutation causes a particular trait.

(4) We observe that individuals with certain traits survive and reproduce in certain populations. For example, we observe how certain variants of bacteria increase and other variants decrease in a population of bacteria.

(5) We observe evolution - we see that populations do change over generations. If the changes are large enough, we call the population a new species.

They took good care...



Artificial selection is one of the methods farmers and scientists continue to use to produce new kinds of plants and animals. By selecting certain individuals for breeding, we may be able to get bigger potatoes, sweeter grapes, faster growing wheat, cows that give more milk, and chickens that are healthier.

Once, some people said, "We want mustard leaves that taste like mango!"

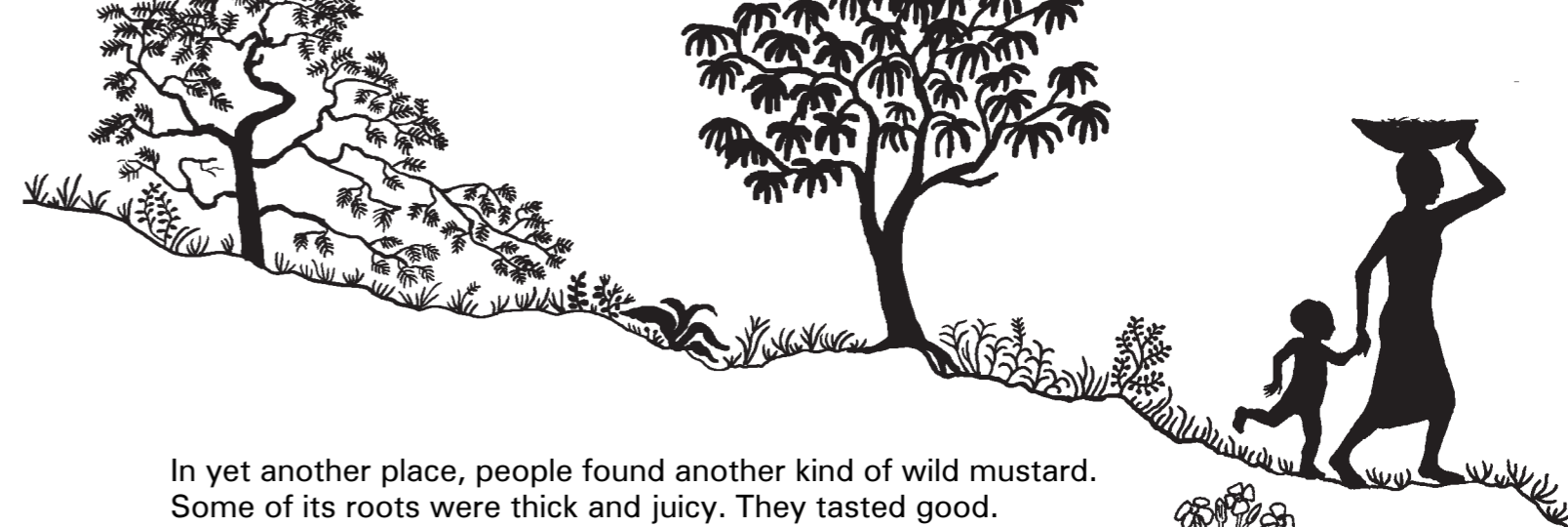
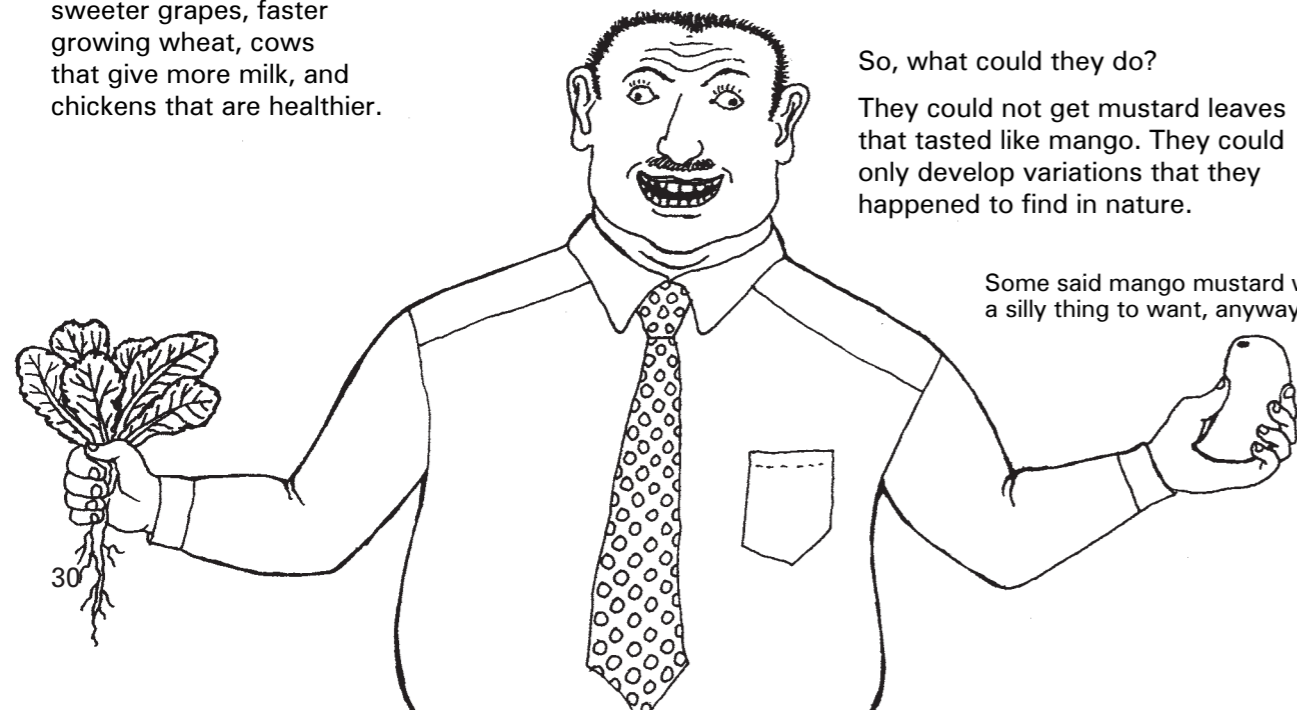
Do you think it is possible?

They looked everywhere for a mustard plant that tasted like mango. But they could not find a single mustard plant that tasted even slightly like mango.

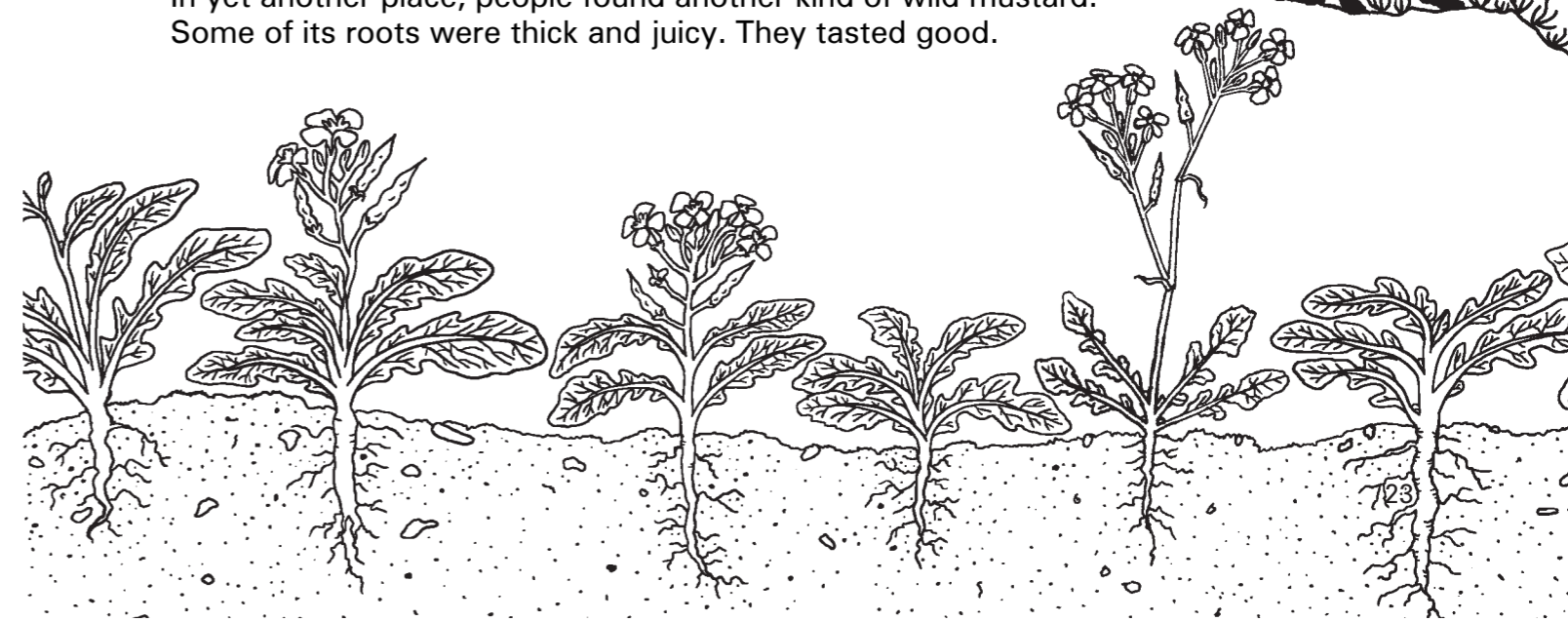
So, what could they do?

They could not get mustard leaves that tasted like mango. They could only develop variations that they happened to find in nature.

Some said mango mustard was a silly thing to want, anyway!



In yet another place, people found another kind of wild mustard. Some of its roots were thick and juicy. They tasted good.

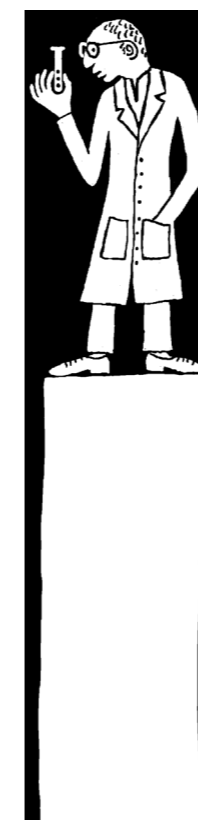
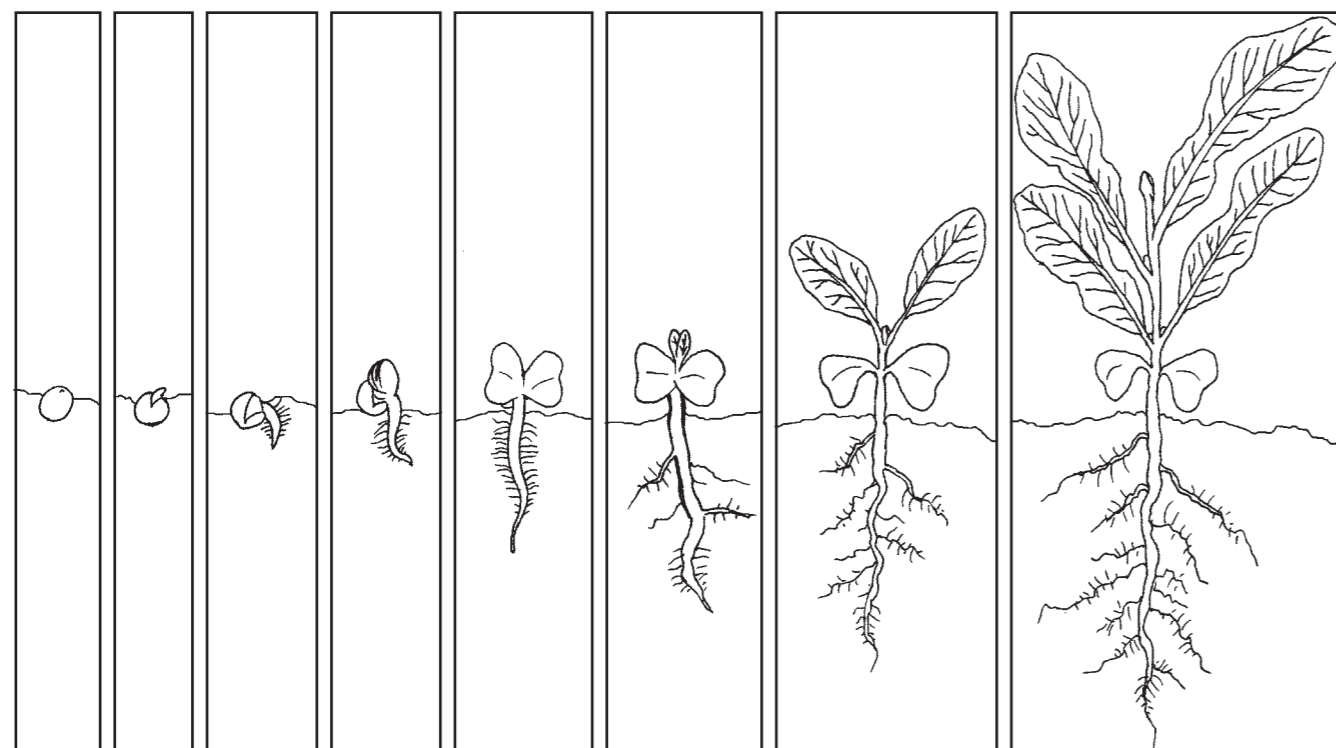


The mustard seeds sprouted.

The roots grew into the soil.

The shoots grew into the air.

Some buds grew into leaves.



Was it really science?

There is a lot of evidence that our ancestors developed new crops like cabbage and cauliflower through artificial selection. The evidence indicates that cabbage and cauliflower were developed several thousand years ago.

But some people do not agree that when our ancestors did this they were doing science. They say that science began more recently in Europe as a result of the Renaissance (which began only in the 14th century). They say that science was what Galileo did when he built a telescope and studied the moons of Jupiter. They say that farmers were not scientists. Farmers were illiterate - they did not write careful records of what they did. They may have made guesses, but they did not make theories or hypotheses. They did not work systemically. They did not have an explicit understanding of artificial selection.

It is true that ancient farmers did not write records of what they did. But maybe we are being biased when we say that

science cannot be done without writing. Or maybe we are not recognising the accomplishments of farmers because they were not 'upper caste' or 'upper class' - they were just labourers.

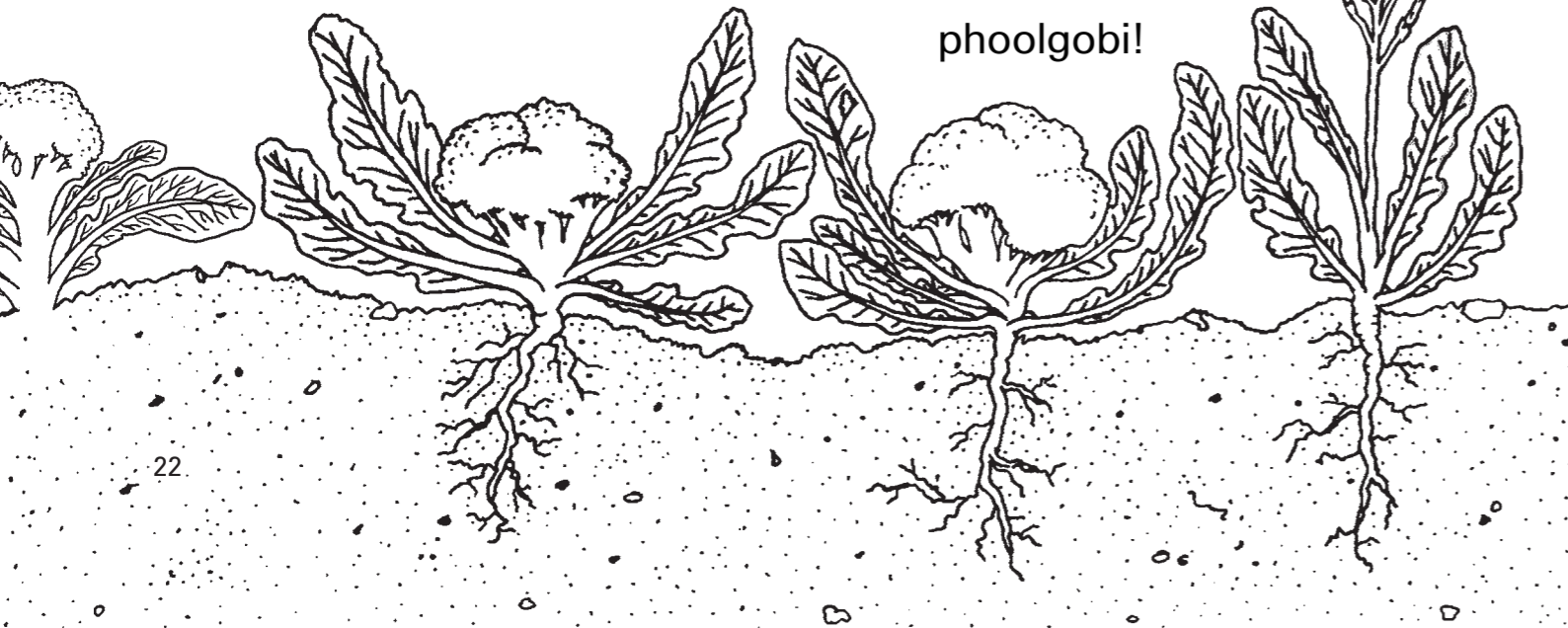
Certainly early farmers must have asked questions like those shown on the opposite page. And they must have learned through a process of trial and error. Aren't experiments also a process of trial and error? In the process of trial and error our ancestors must have also guessed or tried to predict what the results would be. Did they base their predictions on theories which they made through observation, reason and logic? Or did they invent wild stories and myths about spirits and magic, and base their predictions on these myths? Did they believe what authorities said or did they question authorities in order to revise theories and come to new conclusions?

Would it have been possible to develop cabbage and cauliflower if they based their predictions on myths and magic?



After many years of sowing the seeds from the plants with the tastiest undeveloped flowers, look what they got -

phoolgobi!



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Now, suppose there were no people.

Could a similar thing happen without people?
Could wild mustard give rise to mooli without people?
Could it happen without intention?

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APPENDIX: A few more things to think about...

When people produce new types of crops through the process of artificial selection, they are doing science.

They ask questions:

"Why do the mustard seeds grown in this field taste more pungent than the mustard seeds grown in that field? Is it because of the soil?"

"Do more seeds sprout if we plant them deeper underground?"

"How can we get larger mooli?"



They make hypotheses and do experiments:

"Let's have the plants closer together in one row and farther apart in the other row, and see which gives a better crop."

"I think the reason the cabbage last year did not form heads was that the weather was too hot. Heat makes the plants grow tall. So this year let's plant the cabbage earlier in the season."

They make observations and analyse results:

"See how shady it is here... I think the reason the seeds did not germinate was that they did not get enough sun on this side."



They communicate:

"The people in the next village have some strange looking cabbage. Maybe we should get some seeds from it."

However, farmers' science has not progressed as much as it could have because farmers did not and do not have access to good education or communication. The Brahminisation of science and the hierarchal structure of education has been a large problem.

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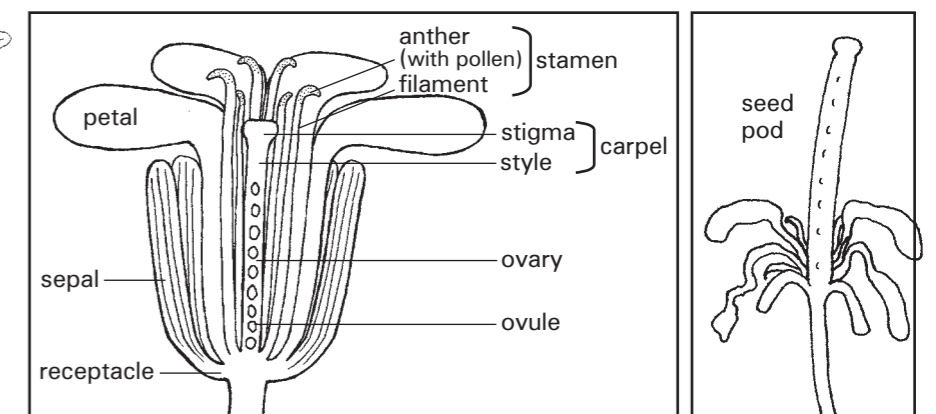
Green leaves grew larger.

The plants grew taller.

Some buds grew into flowers.

Flowers got pollinated.

Pollinated flowers grew into seed pods.



7

Suppose once upon a time,
in a place without people,
there is a population of wild mustard.

As you can see, in any population
there is variation. In this
case some plants have
large roots, and others
have small roots.

The plants with large roots produce
seeds that often give plants with
large roots. Those with small roots
usually produce plants with small roots.

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At the end of the season,
the farmers again chose
the seeds from the
plants with the best
undeveloped flowers.

21

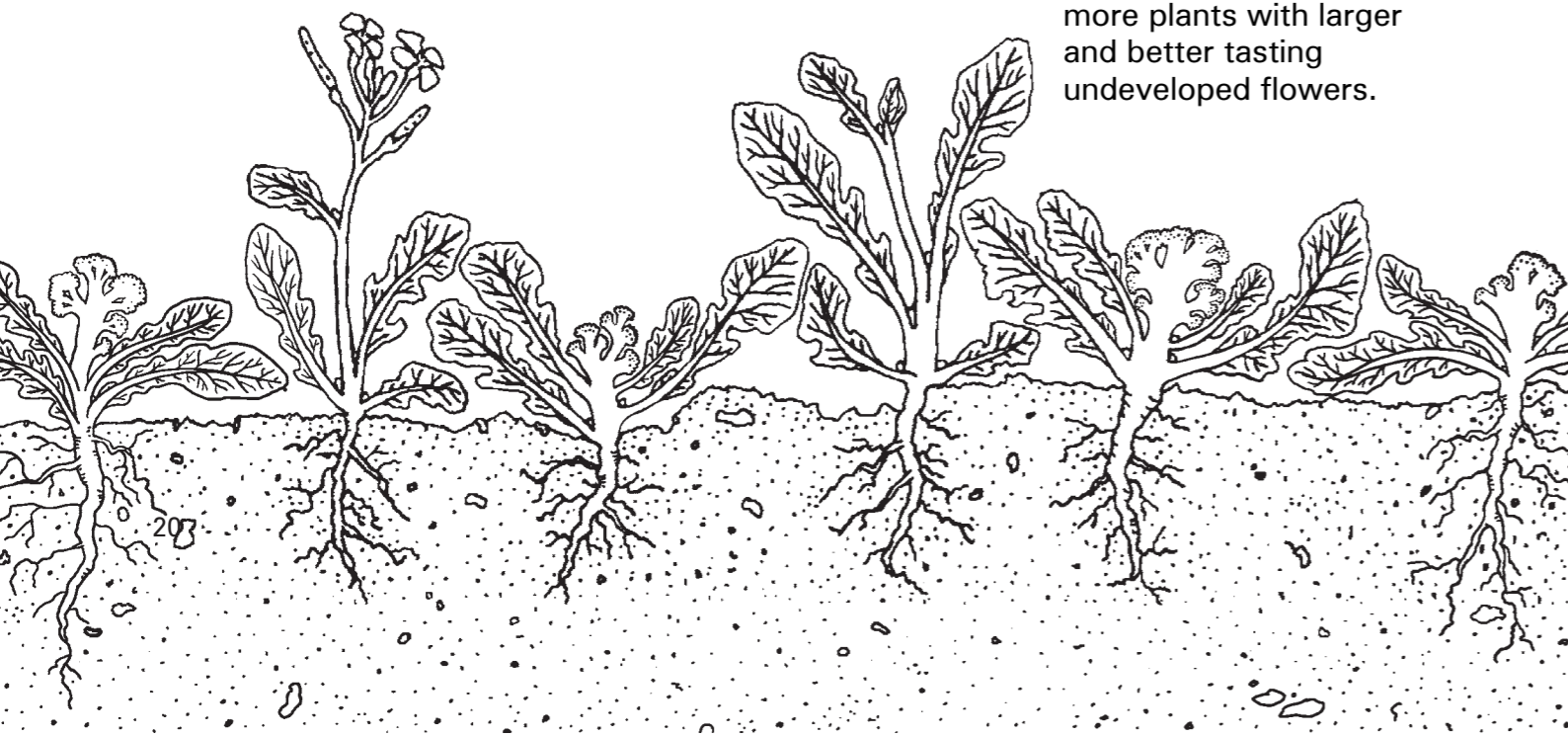
People noticed some differences between the mustard plants.
Look closely.
Can you see any two plants that are the same?

8

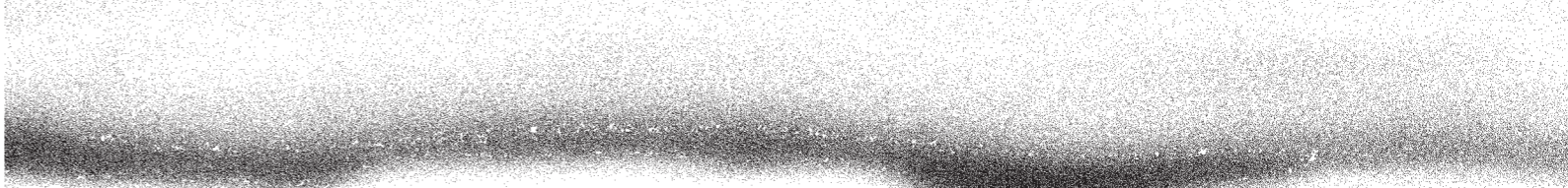
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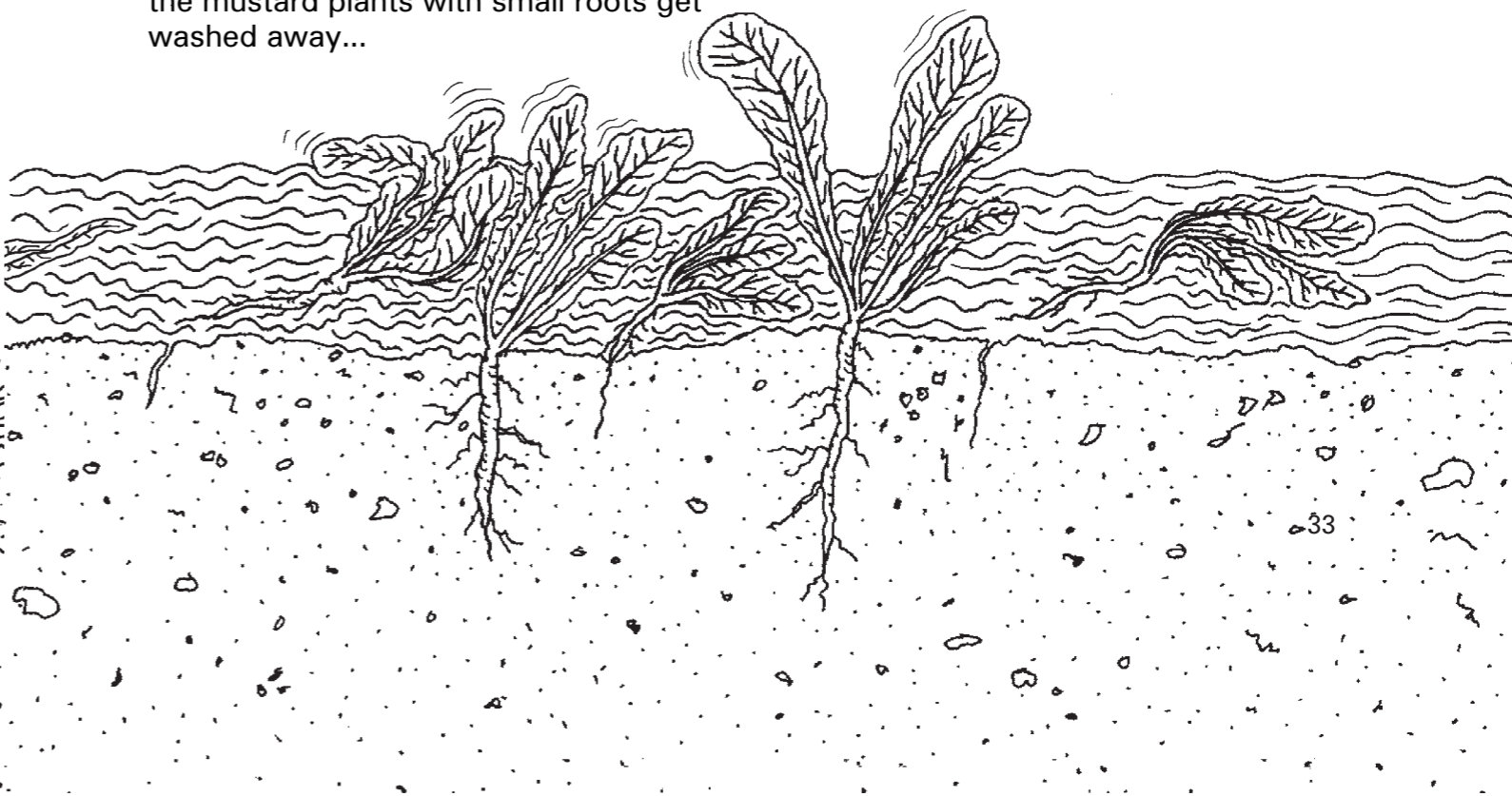
The seeds sprouted and the new crop grew.



Look - this crop has more plants with larger and better tasting undeveloped flowers.



The field often floods, and almost all the mustard plants with small roots get washed away...

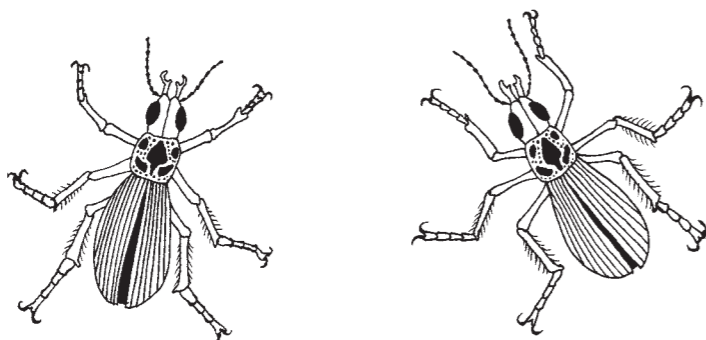


There are a number of mechanisms by which evolution occurs.
In this book we have discussed only two ways:

artificial selection and **natural selection.**

People can change a population on purpose through artificial selection.

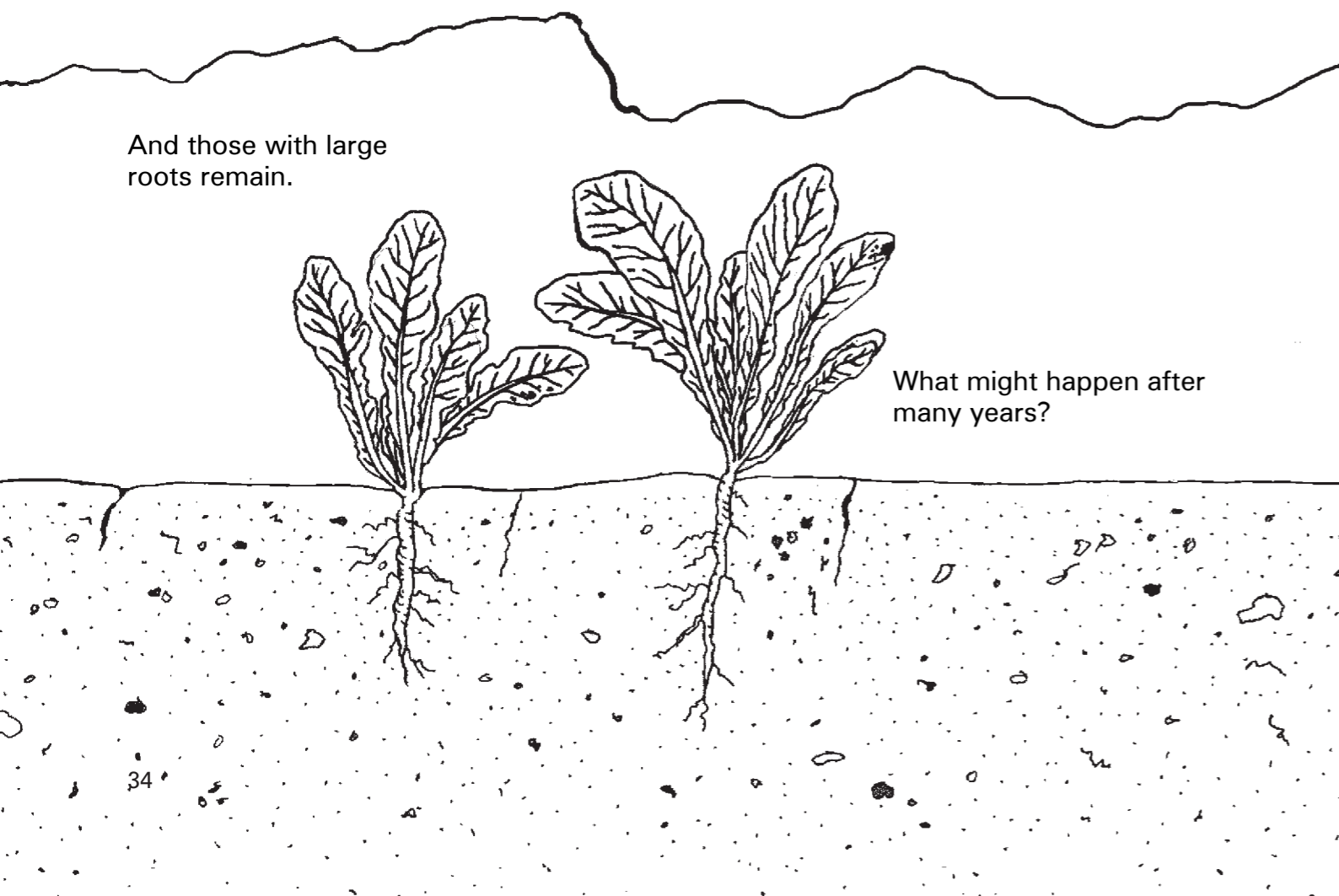
Natural selection does not happen on purpose.



You can't always get what you want!

In what ways are they similar?
In what ways are they different?

Why are they different?
Is it because some had more water? Or less sun?
Or more fertile soil?
Or is it because the seeds they grew from were different?



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A few of the undeveloped flowers went on to produce flowers and seeds.



The farmers gathered the seeds from these plants, and planted them the next year.

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Once some people observed that some mustard plants have seedpods that are longer and contain more mustard seeds than others. They wondered why. They used science to find out.

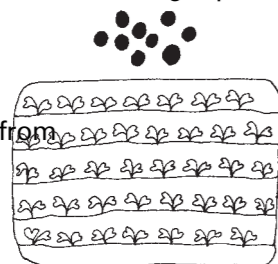
They **QUESTIONED**: Why are some mustard seed pods longer than others?



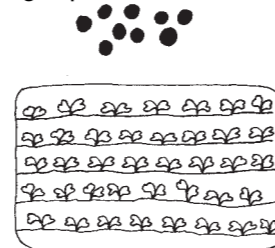
They **HYPOTHESIZED**: Maybe it is because of the seeds from which the plants grew. Maybe seeds from plants with longer pods produce new plants with longer pods.

They did an **EXPERIMENT**:

They planted seeds from short pods in Plot A

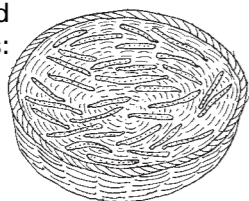


They planted seeds from long pods in Plot B



They got **RESULTS** and **ANALYSED** the results:

Harvest from Plot A



Harvest from Plot B



They **CONCLUDED**:

The seeds determine the size of the seedpods ...more or less.

They asked **MORE QUESTIONS**: Why are a few of the seed pods from Plot B short? Did both plots produce the same number of seed pods? Is the taste of the mustard seeds the same?

10



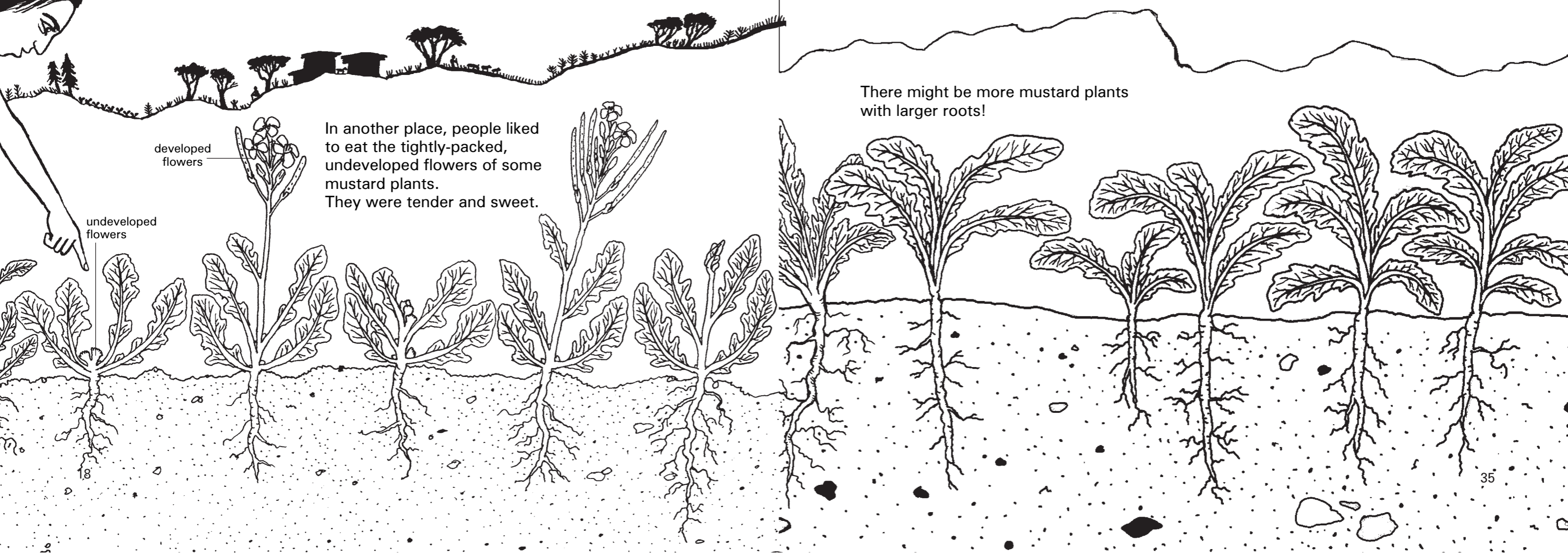
In every population there is variation. No two individuals in a population are exactly alike. Some of the differences can be passed on to future generations (to some extent, they are heritable).

A population is a group of the same kind of living things living in the same place at the same time.

Individual plants, animals, and other organisms do not evolve.

Populations of organisms evolve. If the change is great enough, we say that a new species has evolved.

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developed
flowers

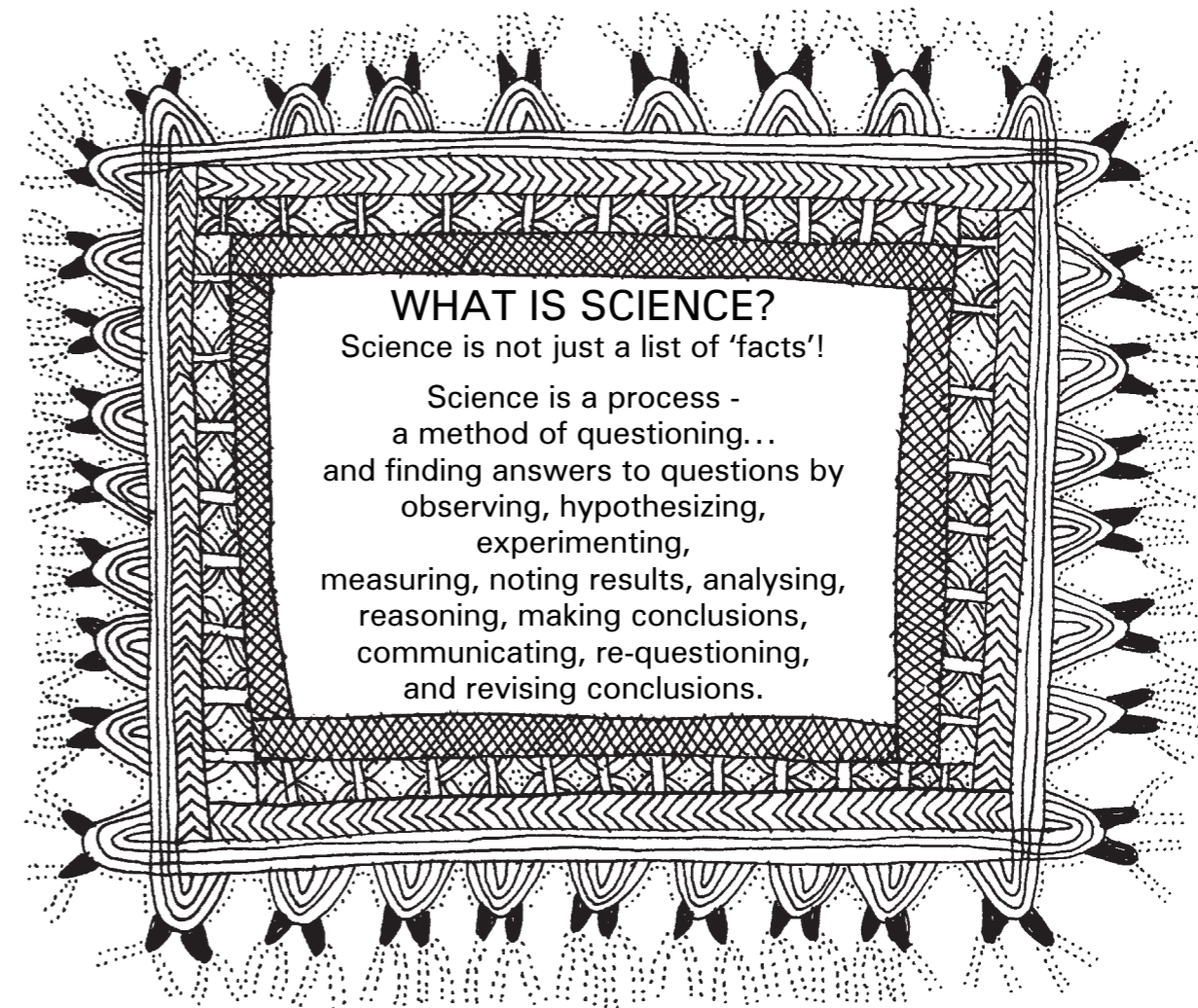
undeveloped
flowers

In another place, people liked
to eat the tightly-packed,
undeveloped flowers of some
mustard plants.
They were tender and sweet.

There might be more mustard plants
with larger roots!

When we do science, we find evidence
that natural selection really does happen,
and it causes evolution.

Evolution is the process by which
populations of plants, animals, and other
living things change over generations.

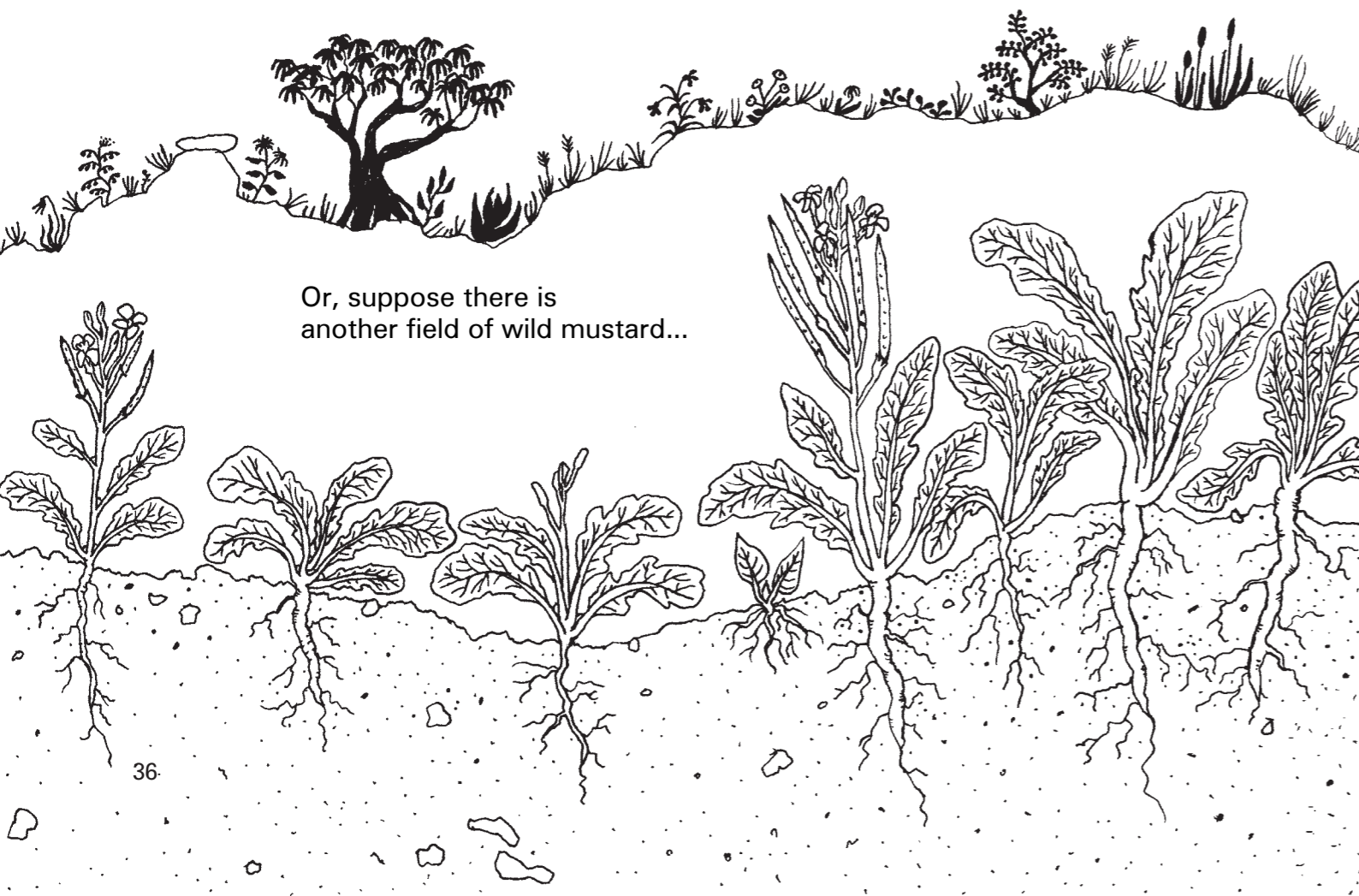


WHAT IS SCIENCE?

Science is not just a list of 'facts'!

Science is a process -
a method of questioning...
and finding answers to questions by
observing, hypothesizing,
experimenting,
measuring, noting results, analysing,
reasoning, making conclusions,
communicating, re-questioning,
and revising conclusions.

There is a lot
of variation in
the scientific
method. The
order is not
fixed, and not
all of these
processes
are always
included.



Or, suppose there is another field of wild mustard...

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Some of our ancestors liked to eat the young mustard leaves that were packed closely together.



Had one plant changed from having less tightly packed leaves to having more tightly packed leaves?

No!

An individual wild mustard plant did not change into a cabbage plant.

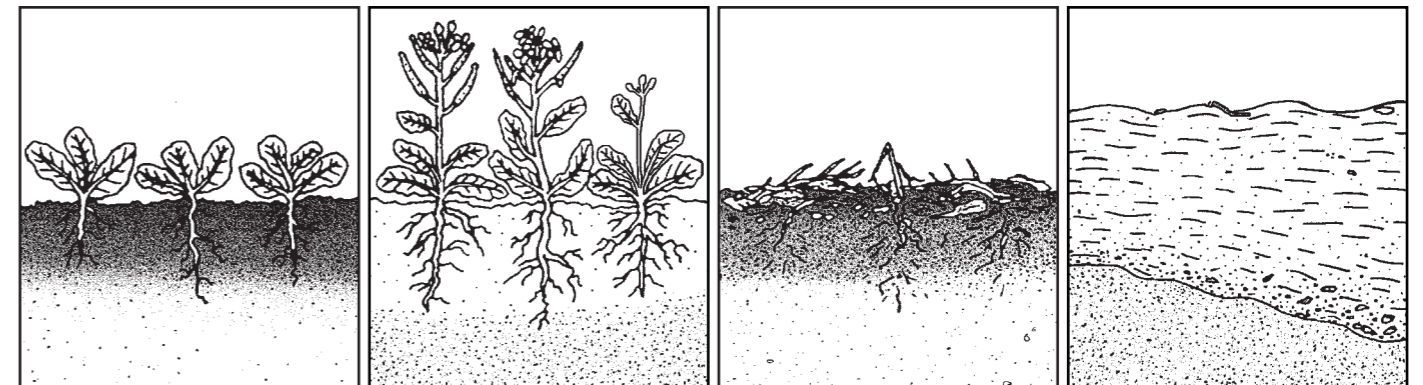
Plants that happened to have tightly packed leaves were the ones that farmers selected for seeds.

The **population** of plants changed after many generations of selection.

A population in which only a few plants had tightly packed leaves evolved into a population in which most plants had tightly packed leaves.

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Organisms affect their environment and the environment affects organisms.



For example, mustard plants remove nutrients from the soil.

When they die and decompose, the plants also add nutrients and organic matter to the soil.

On the other hand, a flood may remove the nutritious topsoil.

Changes in the soil will affect the growth of future generations, and may also make certain variants more or less likely to survive and reproduce.

Many processes are interdependent and interconnected with the process of natural selection.

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After many years, what did they get?

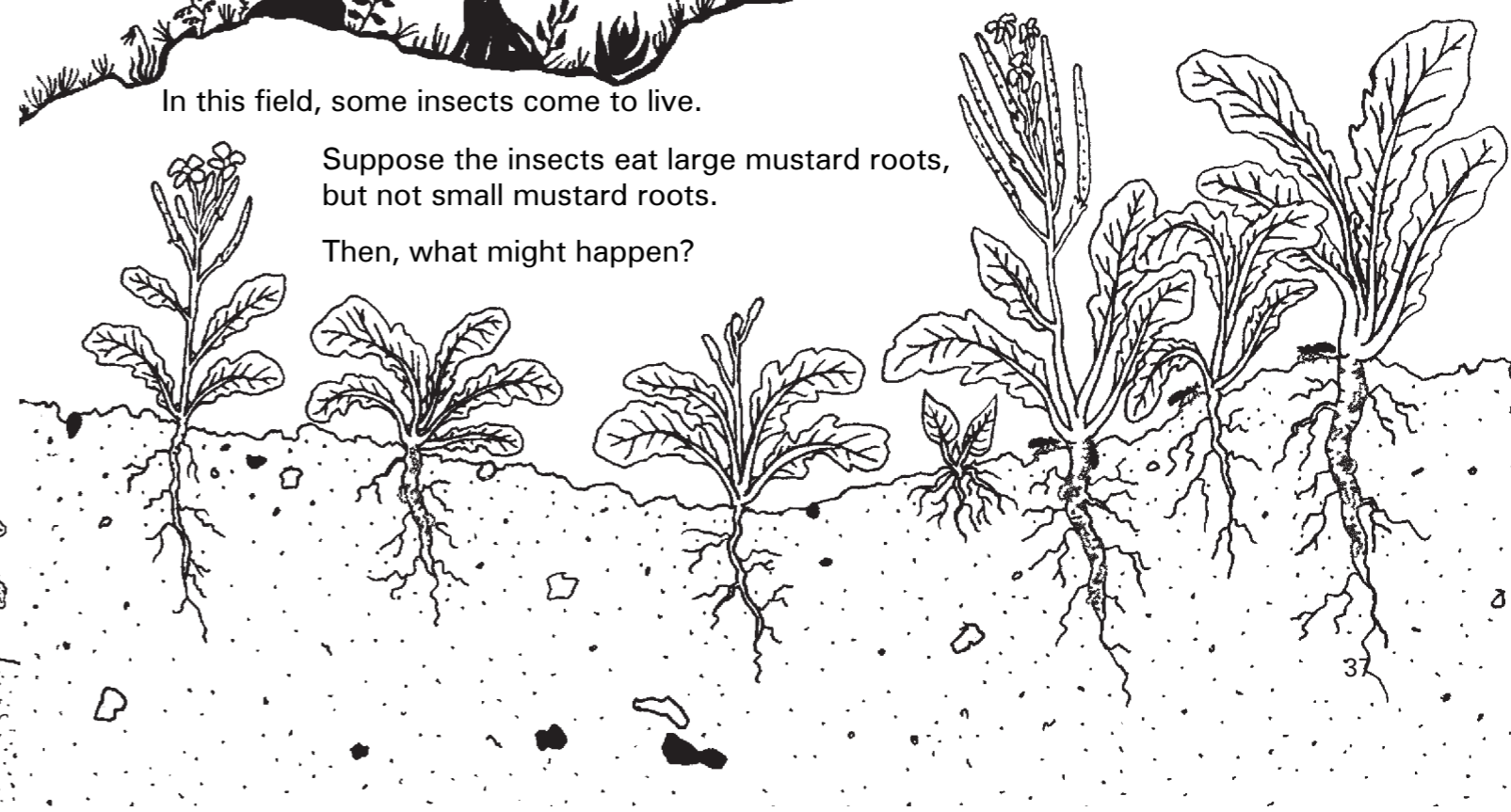
bandgobi!



In this field, some insects come to live.

Suppose the insects eat large mustard roots, but not small mustard roots.

Then, what might happen?

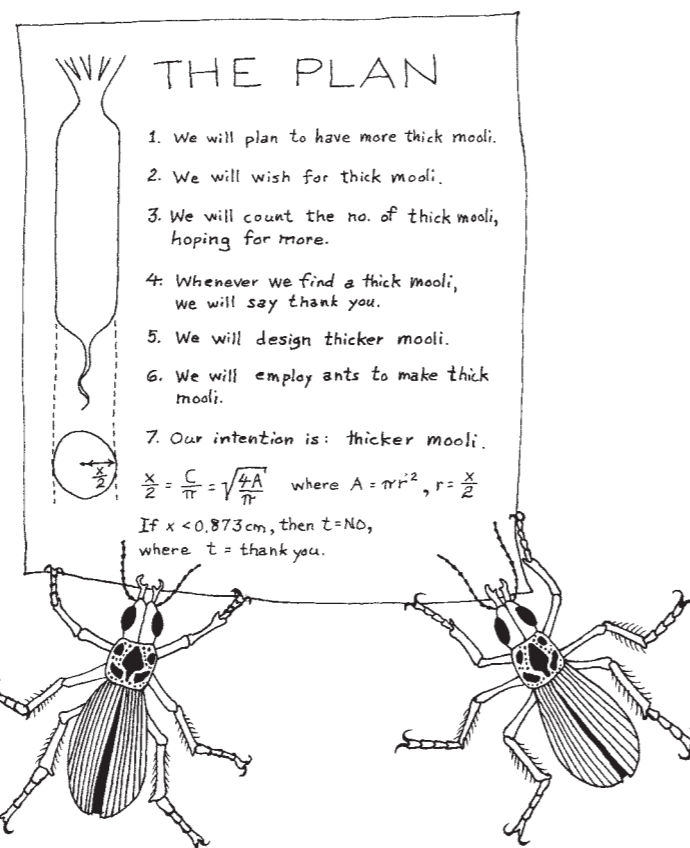


Did the mustard want to get large roots?
Do plants have desires?
What did the insects want?
Do insects have desires?

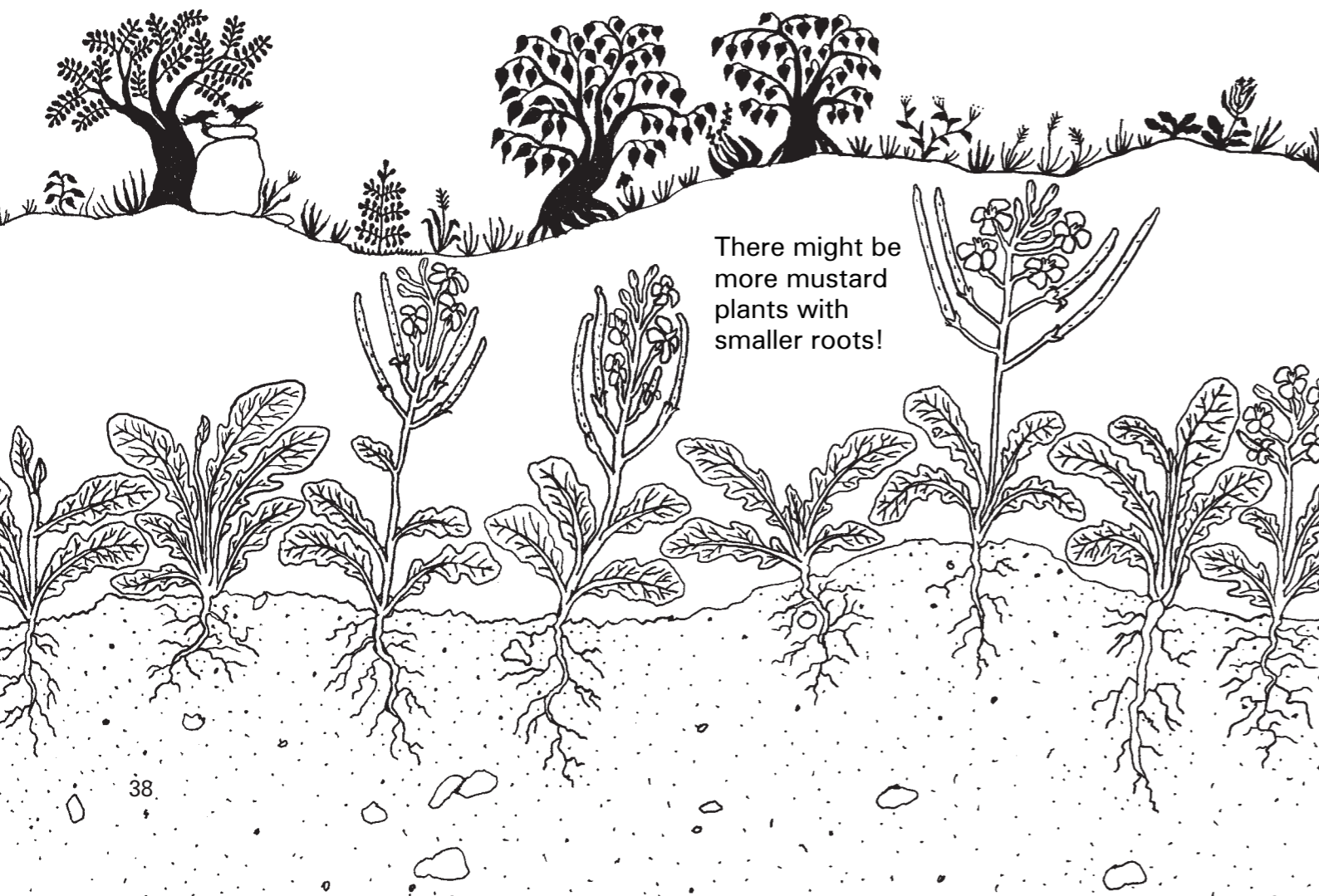
If the insects did have a desire, they would have liked to have more plants with larger, thicker roots - but they got just the opposite. In another case, a plant may evolve that is a good food for a certain animal, but it will not evolve in order to be a good food for that animal.

"Training is everything. The peach was once a bitter almond; cauliflower is nothing but cabbage with a college education."

-Mark Twain, Pudd'nhead Wilson, 1894



They were very tasty!

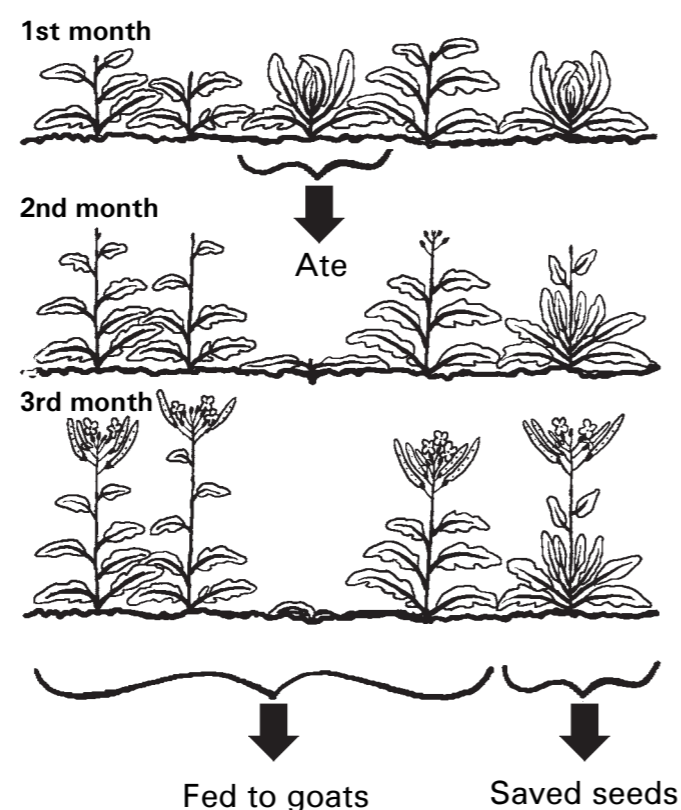


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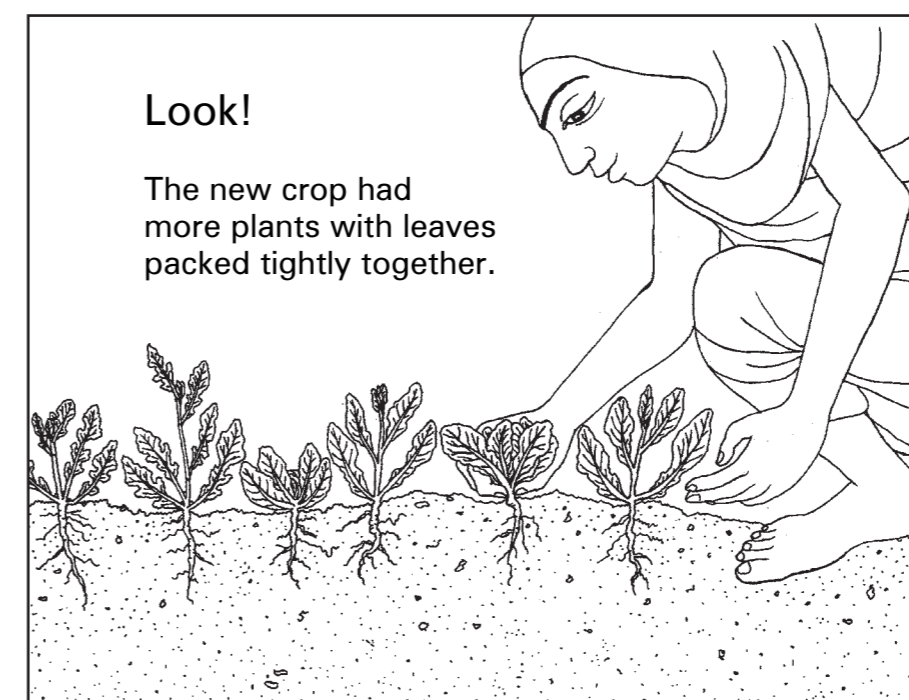
The farmers needed to collect seeds to grow the next year's crop. Instead of eating all the plants, they let some plants grow and produce flowers and seeds.

They wanted to get more plants with tightly packed leaves, so they selected seeds from the plants that had started out with tightly packed leaves.

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They planted these seeds the next year.



Each year they selected seeds from the plants with tightly packed leaves.

If all the best plants were eaten, then the worst plants would be the only ones left to produce seeds for the next year's crop.

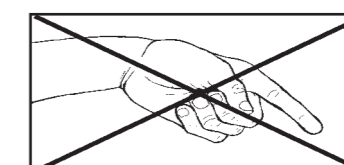
15

This is called **natural selection**.

Here 'natural' means 'not produced by people'.

The population of mustard plants evolved. The change in the population may or may not be a large or sudden change. In this example, the change was not as large as what the farmers got, but the population of mustard did change.

Natural selection is very different from artificial selection. In artificial selection, farmers choose the kinds of plants they want. In natural selection, nobody chooses what they want. There is no plan. There is no design.



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